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Complete Summary

GUIDELINE TITLE

Recommendations for blood pressure measurement in humans and experimental animals: Part 1: blood pressure measurement in humans: a statement for professionals from the Subcommittee of Professional and Public Education of the American Heart Association Council on High Blood Pressure Research.

BIBLIOGRAPHIC SOURCE(S)

Pickering TG, Hall JE, Appel LJ, Falkner BE, Graves J, Hill MN, Jones DW, Kurtz T, Sheps SG, Roccella EJ. Recommendations for blood pressure measurement in humans and experimental animals: Part 1: blood pressure measurement in humans: a statement for professionals from the Subcommittee of Professional and Public Education of the AHA Council on HBP. Circulation 2005 Feb 8;111(5):697-716. [164 references] PubMed

Pickering TG, Hall JE, Appel LJ, Falkner BE, Graves J, Hill MN, Jones DW, Kurtz T, Sheps SG, Roccella EJ. Recommendations for blood pressure measurement in humans and experimental animals: Part 1: blood pressure measurement in humans: a statement for professionals from the Subcommittee of Professional and Public Education of the AHA Council on HBP. Hypertension 2005 Jan;45(1):142-61. PubMed

GUIDELINE STATUS

This is the current release of the guideline.

COMPLETE SUMMARY CONTENT

SCOPE
METHODOLOGY - including Rating Scheme and Cost Analysis
RECOMMENDATIONS
EVIDENCE SUPPORTING THE RECOMMENDATIONS
BENEFITS/HARMS OF IMPLEMENTING THE GUIDELINE RECOMMENDATIONS
IMPLEMENTATION OF THE GUIDELINE
INSTITUTE OF MEDICINE (IOM) NATIONAL HEALTHCARE QUALITY REPORT
CATEGORIES
IDENTIFYING INFORMATION AND AVAILABILITY
DISCLAIMER

SCOPE

DISEASE/CONDITION(S)

Hypertension, including:

- Isolated systolic hypertension
- Isolated systolic hypertension of the young
- Isolated diastolic hypertension
- White-coat hypertension or isolated office hypertension
- Masked hypertension of isolated ambulatory hypertension
- Pseudohypertension
- Orthostatic or postural hypotension

GUIDELINE CATEGORY

Diagnosis
Evaluation

CLINICAL SPECIALTY

Cardiology
Family Practice
Geriatrics
Internal Medicine
Nursing
Obstetrics and Gynecology
Pediatrics
Preventive Medicine

INTENDED USERS

Advanced Practice Nurses
Allied Health Personnel
Nurses
Physician Assistants
Physicians

GUIDELINE OBJECTIVE(S)

To provide clinicians with a standardized set of recommendations for blood pressure measurement in humans that, if followed, should lead to accurate estimation of blood pressure

TARGET POPULATION

Patients in various settings at risk for hypertension including the following special populations:

- Elderly patients
- Patients with pulseless syndromes
- Patients with arrhythmias
- Obese patients
- Children
- Pregnant women

INTERVENTIONS AND PRACTICES CONSIDERED

1. Blood pressure measurement methods
   - Auscultatory method using:
     - Mercury sphygmomanometer
     - Aneroid sphygmomanometer
     - Hybrid sphygmomanometer
   - Oscillometric technique
   - Finger cuff method of Penaz
   - Ultrasound techniques
   - Tonometry
   - Location of measurement (arm, wrist, finger)
   - Validation of monitors
2. Blood pressure measurement in the clinic or office
   - Subject preparation
   - Choice of blood pressure measurement device
   - Selection of proper cuff size
   - Use of sitting or supine body position
   - Positioning of arm; use of right or left arm
   - Cuff placement and use of stethoscope
   - Use of proper inflation/deflation techniques
   - Limiting observer error
   - Use of multiple blood pressure readings
   - Use of automated devices
3. Training, evaluation, and retraining of observers in required competencies
4. Blood pressure measurement in other settings
   - Measurement in acute care
   - Measurement in public places
5. Self-measurement
6. Ambulatory blood pressure measurement
7. Blood pressure recording in special situations
   - Elderly patients
   - Patients with pulseless syndromes
   - Patients with arrhythmias
   - Obese patients
   - Children
   - Pregnant patients

MAJOR OUTCOMES CONSIDERED

- Accuracy of blood pressure measurement using various methods
- Diagnostic and prognostic value of various methods of blood pressure measurement

METHODOLOGY

METHODS USED TO COLLECT/SELECT EVIDENCE

Searches of Electronic Databases

DESCRIPTION OF METHODS USED TO COLLECT/SELECT THE EVIDENCE

Not stated

NUMBER OF SOURCE DOCUMENTS

Not stated

METHODS USED TO ASSESS THE QUALITY AND STRENGTH OF THE EVIDENCE

Not stated

RATING SCHEME FOR THE STRENGTH OF THE EVIDENCE

Not applicable

METHODS USED TO ANALYZE THE EVIDENCE

Review
Review of Published Meta-Analyses

DESCRIPTION OF THE METHODS USED TO ANALYZE THE EVIDENCE

Not stated

METHODS USED TO FORMULATE THE RECOMMENDATIONS

Not stated

RATING SCHEME FOR THE STRENGTH OF THE RECOMMENDATIONS

Not applicable

COST ANALYSIS

A formal cost analysis was not performed and published cost analyses were not reviewed.

METHOD OF GUIDELINE VALIDATION

Peer Review

DESCRIPTION OF METHOD OF GUIDELINE VALIDATION

Expert peer review of American Heart Association (AHA) scientific statements is conducted at the AHA National Center.

This statement was approved by the American Heart Association Science Advisory and Coordinating Committee on October 13, 2004.

MAJOR RECOMMENDATIONS

Blood Pressure Measurement Methods

The auscultatory method has been the mainstay of clinical blood pressure measurement for as long as blood pressure has been measured but is gradually being supplanted by other techniques that are more suited to automated measurement.

Please refer to the original guideline document for a full discussion of blood pressure measurement methods, techniques, and devices.

Validation of Monitors

All monitors in clinical use should be tested for accuracy. This involves 2 stages. First, all oscillometric automated monitors that provide read-outs of systolic and diastolic pressure should be subjected by independent investigators to formal validation protocols. The original 2 protocols that gained the widest acceptance were developed by the Association for the Advancement of Medical Instrumentation (AAMI) in 1987 and the British Hypertension Society (BHS) in 1990, with revisions to both in 1993, and to AAMI in 2002. These required testing of a device against 2 trained human observers in 85 subjects, which made validation studies difficult to perform. One consequence of this has been that there are still many devices on the market that have never been adequately validated. More recently, an international group of experts who are members of the European Society of Hypertension Working Group on Blood Pressure Monitoring has produced an International Protocol that could replace the 2 earlier versions and is easier to perform. Briefly, it requires comparison of the device readings (4 in all) alternating with 5 mercury readings taken by 2 trained observers. Devices are recommended for approval if both systolic and diastolic readings taken are at least within 5 mm Hg of each other for at least 50% of readings.

It is recommended that only those devices that have passed this or similar tests should be used in practice. However, the fact that a device passed a validation test does not mean that it will provide accurate readings in all patients. There can be substantial numbers of individual subjects in whom the error is consistently >5 mm Hg with a device that has achieved a passing grade. This may be more likely to occur in elderly or diabetic patients. For this reason, it is recommended that each oscillometric monitor should be validated on each patient before the readings are accepted. No formal protocol has yet been developed for doing this, but if sequential readings are taken with a mercury sphygmomanometer and the device, then major inaccuracies can be detected.

Another problem is that manufacturers may change the model number after a device has been tested without indicating whether the measurement algorithm has also been changed.

With nonautomatic devices, such as mercury and aneroid monitors, it is recommended that the accuracy of the pressure registration mechanism be checked. In the case of mercury sphygmomanometers, this involves checking that the upper curve of the meniscus of the mercury column is at 0 mm Hg, that the column is free of dirt, and that it rises and falls freely during cuff inflation and deflation.

Aneroid devices or other nonmercury devices should be checked by connecting the manometer to a mercury column or an electronic testing device with a Y-tube. The needle should rest at the zero point before the cuff is inflated and should register a reading that is within 4 mm Hg of the mercury column when the cuff is inflated to pressures of 100 and 200 mm Hg. The needle should return to zero after deflation.

Blood Pressure (BP) Measurement in the Clinic or Office

Accurate auscultatory office blood pressure measurement is the bedrock of the diagnosis and treatment of hypertension and has been the standard method used in the major epidemiologic and treatment trials of the past 50 years. However, it is becoming increasingly clear that as it is used in everyday practice, there are major shortcomings. Thus, surveys of mercury devices in clinical practices have shown that there are frequently mechanical defects, and physicians rarely follow official guidelines for their use. Added to these is the phenomenon of the white coat effect, whereby the recorded blood pressure may be unrepresentative of the patient's true blood pressure.

Subject Preparation

A number of factors related to the subject can cause significant deviations in measured blood pressure. These include room temperature, exercise, alcohol or nicotine consumption, positioning of the arm, muscle tension, bladder distension, talking, and background noise. The patient should be asked to remove all clothing that covers the location of cuff placement. The individual should be comfortably seated, with the legs uncrossed, and the back and arm supported, such that the middle of the cuff on the upper arm is at the level of the right atrium (the mid-point of the sternum). Measurements made while the patient is on an examining table do not fulfill these criteria and should preferably be made while the patient is seated in a chair. At the initial visit, blood pressure should be measured in both arms. The patient should be instructed to relax as much as possible and to not talk during the measurement procedure; ideally, 5 minutes should elapse before the first reading is taken.

Choice of Blood Pressure Measurement Devices

The "gold standard" device for office blood pressure measurement has been the mercury sphygmomanometer, but these are being removed from clinical practice because of environmental concerns about mercury contamination. Mercury sphygmomanometers are already banned in Veterans Administration hospitals. There is a role for other types of device in office use, both as a substitute for the traditional mercury readings (e.g., aneroid and hybrid sphygmomanometers) and as supplements to them (e.g., oscillometric automatic devices). However, because there is currently no generally accepted replacement for mercury, it is

recommended that, if available, a properly maintained mercury sphygmomanometer be used for routine office measurements. Mercury sphygmomanometers are critical for evaluating the accuracy of any type of nonmercury device. Nonmercury pressurometers that use electronic pressure transducers with a digital read-out are available for calibrating the pressure detection systems of aneroid or oscillometric devices.

Cuff Size

Von Recklinghausen in 1901 recognized that Riva Rocci's device for determination of accurate systolic blood pressure by palpation had a significant flaw, its 5-cm-width cuff. Multiple authors have shown that the error in blood pressure measurement is larger when the cuff is too small relative to the patient's arm circumference than when it is too large. Previous epidemiological data from Britain and Ireland had suggested that arm circumferences of >34 cm were uncommon. Data from National Health And Nutrition Examination Survey (NHANES) III and NHANES 2000 have shown the opposite in the United States. In the United States during the period from 1988 to 2000, there has been a significant increase in mean arm circumference and an increase in the frequency of arm circumferences of >33 cm was found because of increasing weight in the American population. This should not be surprising, because the prevalence of obesity in the United States has increased from 22.9% in NHANES III (1988 to 1994) to >30% in 2000. Similar data regarding the increased frequency of larger arm circumferences were also found in a study of a referral practice of hypertensive subjects, in which a striking 61% of 430 subjects had an arm circumference of >33 cm. Recognition of the increasing need for the "large adult" cuff, or even the thigh cuff, for accurate blood pressure measurement is critical, because frequently in practice only the standard adult size has been demonstrated to be available. More importantly, it has been demonstrated that the most frequent error in measuring blood pressure in the outpatient clinic is "miscuffing," with undercuffing large arms accounting for 84% of the "miscuffings."

The "ideal" cuff should have a bladder length that is 80% and a width that is at least 40% of arm circumference (a length-to-width ratio of 2:1). A recent study comparing intra-arterial and auscultatory blood pressure concluded that the error is minimized with a cuff width of 46% of the arm circumference. The recommended cuff sizes are:

- For arm circumference of 22 to 26 cm, the cuff should be "small adult" size: 12X22 cm
- For arm circumference of 27 to 34 cm, the cuff should be "adult" size: 16X30 cm
- For arm circumference of 35 to 44 cm, the cuff should be "large adult" size: 16X36 cm
- For arm circumference of 45 to 52 cm, the cuff should be "adult thigh" size: 16X42 cm

The optimum ratios of width and length to arm circumference are shown for the small adult and standard adult cuffs. For the large adult and thigh cuffs, the ideal width ratio of 46% of arm circumference is not practical, because it would result in a width of 20 cm and 24 cm, respectively. These widths would give a cuff that would not be clinically usable for most patients, so for the larger cuffs, a less than

ideal ratio of width to arm circumference must be accepted. The ideal ratio of length to arm circumference is maintained in all 4 cuffs.

In practice, bladder width is easily appreciated by the clinician but bladder length often is not, because the bladder is enclosed in the cuff. To further complicate the issue for clinicians, there are no standards for manufacturers of different sizes of blood pressure cuff. This has led to significant differences in which arm circumferences are accurately measured by individual manufacturers' standard adult and large adult cuffs.

Individual cuffs should be labeled with the ranges of arm circumferences, to which they can be correctly applied, preferably by having lines that show whether the cuff size is appropriate when it is wrapped around the arm. In patients with morbid obesity, one will encounter very large arm circumferences with short upper arm length. This geometry often cannot be correctly cuffed, even with the thigh cuff. In this circumstance, the clinician may measure blood pressure from a cuff placed on the forearm and listening for sounds over the radial artery (although this may overestimate systolic blood pressure) or use a validated wrist blood pressure monitor held at the level of the heart.

Effects of Body Position

Blood pressure measurement is most commonly made in either the sitting or the supine position, but the 2 positions give different measurements. It is widely accepted that diastolic pressure measured while sitting is higher than when measured supine (by approximately 5 mm Hg), although there is less agreement about systolic pressure. When the arm position is meticulously adjusted so that the cuff is at the level of the right atrium in both positions, the systolic pressure has been reported to be 8 mm Hg higher in the supine than the upright position.

Other considerations include the position of the back and legs. If the back is not supported (as when the patient is seated on an examination table as opposed to a chair), the diastolic pressure may be increased by 6 mm Hg. Crossing the legs may raise systolic pressure by 2 to 8 mm Hg.

In the supine position, the right atrium is approximately halfway between the bed and the level of the sternum; thus, if the arm is resting on the bed, it will be below heart level. For this reason, when measurements are taken in the supine position the arm should be supported with a pillow. In the sitting position, the right atrium level is the midpoint of the sternum or the fourth intercostal space.

Effects of Arm Position

The position of the arm can have a major influence when the blood pressure is measured; if the upper arm is below the level of the right atrium (when the arm is hanging down while in the sitting position), the readings will be too high. Similarly, if the arm is above the heart level, the readings will be too low. These differences can be attributed to the effects of hydrostatic pressure and may be 10 mm Hg or more, or 2 mm Hg for every inch above or below the heart level.

Other physiological factors that may influence the blood pressure during the measurement process include muscle tension. If the arm is held up by the patient (as opposed to being supported by the observer), the isometric exercise will raise the pressure.

Differences Between the Two Arms

Several studies have compared the blood pressure measured in both arms, mostly using the auscultatory technique. Almost all have reported finding differences, but there is no clear pattern; thus, the difference does not appear to be determined by whether the subject is right- or left-handed. One of the largest studies was conducted in 400 subjects using simultaneous measurements with oscillometric devices, which found no systematic differences between the 2 arms, but 20% of subjects had differences of >10 mm Hg. Although these findings are disturbing, it is not clear to what extent the differences were consistent and reproducible, as opposed to being the result of inherent blood pressure variability. Nevertheless, it is recommended that blood pressure should be checked in both arms at the first examination. This may be helpful in detecting coarctation of the aorta and upper extremity arterial obstruction. When there is a consistent interarm difference, the arm with the higher pressure should be used. In women who have had a mastectomy, blood pressure can be measured in both arms unless there is lymphedema.

Cuff Placement and Stethoscope

Cuff placement must be preceded by selection of the appropriate cuff size for the subject's arm circumference. The observer must first palpate the brachial artery in the antecubital fossa and place the midline of the bladder of the cuff (commonly marked on the cuff by the manufacturer) so that it is over the arterial pulsation over the patient's bare upper arm. The sleeve should not be rolled up such that it has a tourniquet effect above the blood pressure cuff. The lower end of the cuff should be 2 to 3 cm above the antecubital fossa to allow room for placement of the stethoscope. However, if a cuff that leaves such space has a bladder length that does not sufficiently encircle the arm (at least 80%), a larger cuff should be used, recognizing that if the cuff touches the stethoscope, artifactual noise will be generated. The cuff is then pulled snugly around the bare upper arm. Neither the observer nor the patient should talk during the measurement. Phase 1 (systolic) and phase 5 (diastolic) Korotkoff sounds are best heard using the bell of the stethoscope over the palpated brachial artery in the antecubital fossa, although some studies have shown that there is little difference when using the bell or the diaphragm. The key to good measurement is the use of a high-quality stethoscope with short tubing, because inexpensive models may lack good tonal transmission properties required for accurate auscultatory measurement.

Inflation/Deflation System

Indirect blood pressure measurement requires that occlusion of the brachial artery is produced by gradual inflation and deflation of an appropriately sized cuff. The tubing from the device to the cuff must be of sufficient length (70 cm or more) to allow for its function in the office setting. Successful inflation and deflation requires an airtight system; ongoing inspection and maintenance of the tubing for deterioration of the rubber (cracking) and the release valve are required. The cuff

should initially be inflated to at least 30 mm Hg above the point at which the radial pulse disappears. The rate of deflation has a significant effect on blood pressure determination. Deflation rates >2 mm per second can lead to a significant underestimation of systolic and overestimation of diastolic blood pressure. Automated devices with a linear deflation rate may have improved accuracy over the more common circumstances in automated devices that have stepwise deflation. It is recommended that a deflation rate of 2 to 3 mm Hg per second (or per pulse when the heart rate is very slow) be used.

Important Points for Clinical Blood Pressure Measurement

- The patient should be seated comfortably with the back supported and the upper arm bared without constrictive clothing. The legs should not be crossed.
- The arm should be supported at heart level, and the bladder of the cuff should encircle at least 80% of the arm circumference.
- The mercury column should be deflated at 2 to 3 mm/s, and the first and last audible sounds should be taken as systolic and diastolic pressure. The column should be read to the nearest 2 mm Hg.
- Neither the patient nor the observer should talk during the measurement.

Observer

The observer is the most critical component of accurate blood pressure measurement. For accurate blood pressure measurement, the observer must: (1) be properly trained in the techniques of blood pressure measurement; (2) use an accurate and properly maintained device; (3) recognize subject factors, such as anxiety and recent nicotine use, that would adversely affect blood pressure measurements; (4) position the subject appropriately; (5) select the correct cuff and position it correctly; and (6) perform the measurement using the auscultatory or automated oscillometric method and accurately record the values obtained.

Observer error is a major limitation of the auscultatory method. Systematic errors lead to intra-observer and interobserver error. Terminal digit preference is perhaps the most common manifestation of suboptimal blood pressure determination. It is generally recommended that the observer should read the blood pressure to the nearest 2 mm Hg, but an inappropriate excess in the recording of "zero" as the last digit in auscultatory blood pressure determinations has been reported by multiple investigators in clinical and research settings. Digit bias or digit prejudice is particularly common when the observer recognizes a specific threshold value for blood pressure and, depending on the circumstances, records a pressure just above or below that number. A good example is the Syst-Eur Trial, which showed both increased zero preference and a significant digit bias for 148 mm Hg systolic, the threshold for successful treatment in that trial.

Number of Measurements

It is well recognized that the predictive power of multiple blood pressure determinations is much greater than a single office reading. One of the potential advantages of supplementing auscultatory readings with readings taken by an automated device is the ability to obtain a larger number of readings. When a series of readings is taken, the first is typically the highest. A minimum of 2

readings should be taken at intervals of at least 1 minute, and the average of those readings should be used to represent the patient's blood pressure. If there is >5 mm Hg difference between the first and second readings, additional (1 or 2) readings should be obtained, and then the average of these multiple readings is used.

Automated Methods

Automated oscillometric blood pressure devices are increasingly being used in office blood pressure measurement, as well as for home and ambulatory monitoring. When they are used in the office, the readings are typically lower than readings taken by a physician or nurse. The potential advantages of automated measurement in the office are the elimination of observer error, minimizing the white coat effect, and increasing the number of readings. The main disadvantages are the error inherent in the oscillometric method and the fact that epidemiologic data are mostly based on auscultated blood pressure measures.

Automated devices may also offer the opportunity to avoid expensive and repetitive training of health care professionals in auscultation, which is necessary to reduce observer errors. Their use still requires careful patient evaluation for caffeine or nicotine use, selection of the correct cuff size, and proper patient positioning if accurate blood pressures are to be obtained. Devices are now available that can take a series of sequential readings and automatically average them.

The White Coat Effect and the Differences Between Physician and Nurse Blood Pressure Measurements

The initial epidemiological studies of hypertension and the first major hypertension treatment trial (Veterans Administration [VA] Cooperative Study) were performed using physician blood pressure measurements. Since that time, all the major hypertension treatment trials have used a nurse, "a trained observer," or automated blood pressure measurements. In hypertensive patients (but not necessarily in normotensive patients), the blood pressure recorded by a physician or nurse is typically higher than the average daytime level, and this difference is commonly referred to as the white coat effect.

In addition to these effects of the medical environment on blood pressure measurement, there is a recognized difference between blood pressure levels measured by a physician versus a nurse in the same subjects. In the largest study of physician-nurse blood pressure differences, it was found that a nurse recorded significantly lower mean systolic and diastolic pressures than a physician (by 6.3/7.9 mm Hg). This difference is not caused by any difference in technique, because when a dual-headed stethoscope is used and the physician and nurse simultaneously take the blood pressure, the physician-nurse difference is insignificant. In addition, the nurse-recorded blood pressure is usually closer to the patient's daytime average pressure than the pressure recorded by the physician. Because all of the most recent treatment trials of hypertension are based on blood pressure measurements made by nurses or other professionals, but not by physicians, the difference in office blood pressure measured by physicians and nurses suggests that physician blood pressures should not be used exclusively in the routine management of the hypertensive subject.

<u>Training of Observers</u>

As the number and type of blood pressure measurement devices and direct-to-consumer advertising increase, more people are measuring blood pressure more frequently. In medical settings, physicians, nurses, nurses' aids, students, and pharmacists all measure blood pressure and record the values in a patient's records. Outside medical settings, patients, family members, or lay persons also measure blood pressure. The training given to lay observers should be as comprehensive and similar to that recommended for health care professionals in ambulatory and community settings. With careful training even unpaid volunteers in large population surveys can measure blood pressure accurately. However, even with the newer automated devices, the accuracy of the readings can be optimal only if all observers are appropriately trained and retrained and conscientious about using appropriate techniques.

Required Competencies

Before training begins, potential observers should be assessed for physical and cognitive competencies required to perform the procedure. The physical requirements include the following:

- Vision. The observer must be able to see the dial of the manometer or the meniscus of the mercury column at eye level without straining or stretching, and must be able to read well enough to see the sphygmomanometer or digital display no further than 3 feet away.
- Hearing. The observer must be able to hear the appearance and disappearance of Korotkoff sounds.
- Eye/hand/ear coordination. This is required for the use of mercury and aneroid sphygmomanometers but not for the newer electronic technologies.

Training

Traditionally, health professionals are trained in blood pressure measurement in introductory courses on physical assessment. They may receive a classroom lecture with a video on how to measure blood pressure, some laboratory skills training with demonstration and practice on fellow trainees, and mentored experience measuring blood pressure of patients, potential research subjects, or community volunteers. In clinical trials, standardized programs with audiovisual tapes that test and retest accuracy in measurement are extremely effective in training and retraining. In contrast, such training and retraining is not routinely required in nonresearch settings.

Some information is available on the Internet, and the British Hypertension Society has a web-based video that can be used for the training and evaluation of observers.

Evaluation of Observers

Pencil-and-paper questionnaires or interviews can be used to assess knowledge of the correct methodology of blood pressure measurement. The evaluation of observers should include an assessment of their knowledge of the different types

of observer bias, general technique, and the interpretation of the measurements, including an understanding of the normal variability of blood pressure by time of day, exercise, timing of antihypertensive medications, etc. The observers should also know how and when to communicate blood pressure readings gathered at home or other settings to the health care professional responsible for the care of the patient and management of hypertension.

Observers should be aware of the need to use only well-maintained and calibrated equipment, choosing a quiet location with adequate room temperature, correctly positioning the person having blood pressure measured, and ensuring that the person does not talk or move during the measurement.

The skills of the observer should be demonstrated by assessing items such as positioning the patient, selecting the right size cuff, obtaining a valid and reliable measurement, recording the measurement accurately, and appropriate reporting of abnormal levels.

Retraining

Correct blood pressure measurement technique is difficult to maintain without careful attention to all steps in the protocol and retraining. The gold standard for retraining has been set by federally funded multisite clinical trials of hypertension care and control, in which retraining is required of all blood pressure observers every 6 months. Retraining requires competency in cuff selection, patient positioning, no talking, and accurate observation of the blood pressure level by either auditory or visual assessment. Four methods of assessment are used: audio-video test tapes; Y-tube-connected simultaneous readings by 2 trained observers; a written quiz; and direct observation. In the National Heart, Lung, and Blood Institute (NLHBI)-sponsored multisite clinical trials, a senior experienced person is assigned as the central trial master trainer and a master trainer is designated for each site. The central master trainer trains the site master trainers, and they in turn train the observers at each site. This model could be replicated within hospitals, ambulatory care settings, and community agencies. Retraining of all health care professionals is strongly recommended.

Blood Pressure Measurement in Other Settings

Acute Care

Blood pressure measurements in acute care settings, such as the emergency department, dialysis unit, or operating suite, are usually performed to judge vital signs and volume status of the patient rather than the presence or absence of hypertension. Oscillometric devices are widely used for this purpose and may give accurate assessment of mean arterial pressure, but are often inaccurate for registering systolic and diastolic pressure. Blood pressure values obtained in acute care settings are unlikely to be useful for decisions on chronic hypertension management, because of inadequate patient preparation, faulty equipment, and the impact of the acute illness on blood pressure. Still, high readings recorded in the emergency room do predict hypertension on subsequent clinic visits, to some extent, and warrant follow-up.

Blood pressure measurement is also important in the prehospital setting. Multiple techniques of blood pressure determination in the field and ambulance and helicopter transportation environments, including auscultatory, oscillometric, palpation, and use of obliteration of the pulse wave on the pulse oximeter, have been used. All of these suffer from a high degree of error that is worse with systolic blood pressures of <90 mm Hg. In addition, it has been shown that standard equipment used by emergency medical services for blood pressure determination is often highly unreliable. Determining blood pressures in prehospital settings requires a high degree of clinical experience and repetitive measurement. In this setting, establishment of trends in blood pressure before arriving in the more controlled hospital environment is more important than the absolute value of the blood pressure.

An elevated blood pressure in the acute care setting should raise the suspicion that the patient has hypertension, and a referral to the outpatient setting for further evaluation is warranted. Because of the lack of precision of blood pressure measurement (and the impact of bed rest, acute illness, medication administration, and alteration in the patient's usual diet while in the hospital), blood pressures obtained in the acute care setting should not be used to judge the adequacy of blood pressure control.

Public Places

Automated blood pressure devices are commonly found in public places and represent a potential mechanism for increased screening for hypertension. In 1995, Whitcomb et al reported that since the introduction of the VitaStat device in 1976, >8000 devices were in use in the United States, providing >10 million measurements per year. The initial version was the 8000 model, which was never tested by approved protocols and which was found to give very inconsistent results, particularly for systolic pressure. A later model (the 90550) has been tested in a community setting and has also failed to meet the British Hypertension Society (BHS) or Association for the Advancement of Medical Instrumentation (AAMI) criteria for accuracy. Other potential problems with these devices are that the cuff size (23X33 cm) is inadequate for patients with large arms, and that they are not labeled to show when or if there has been recent maintenance and revalidation of the device's performance. Clear demonstration to the user of ongoing device servicing and validation would be critical to acceptance of the devices for public blood pressure screening.

<u>Self-Measurement</u>

Types of Monitor

When self-monitoring or home-monitoring was first used, the majority of studies used aneroid sphygmomanometers. In the past few years, automatic electronic devices have become increasingly popular. The standard type of monitor for home use is now an oscillometric device that records pressure from the brachial artery. Unfortunately, only a few have been subjected to proper validation tests such as the AAMI and BHS protocols, and of 24 devices that have been tested by these, only 5 have passed. An up-to-date list of validated monitors is available. The advantages of electronic monitors have begun to be appreciated by epidemiologists, who have always been greatly concerned about the accuracy of

clinical blood pressure measurement and have paid much attention to the problems of observer error, digit preference, and the other causes of inaccuracy described. It has been argued that the ease of use of the electronic devices and the relative insensitivity to who is actually taking the reading can outweigh any inherent inaccuracy compared with the traditional sphygmomanometer method. This issue remains controversial, however.

Electronic devices are now available that will take blood pressure from the upper arm, wrist, or finger. Although the use of the more distal sites may be more convenient, measurement of blood pressure from the arm (brachial artery) has always been the standard method and is likely to remain so for the foreseeable future. The fact that a device has passed the validation criteria does not guarantee accuracy in the individual patient, and it is essential that each device be checked on each patient before the readings are accepted as being valid (see the previous section on Validation of Monitors). Home-monitoring devices should be checked for accuracy every 1 to 2 years.

Clinical Applications

Home- or self-monitoring has numerous advantages over ambulatory monitoring, principal among which are that it is relatively cheap and provides a convenient way for monitoring blood pressure over long periods of time. There is some evidence that it improves both therapeutic compliance and blood pressure control. However, technical, economic, and behavioral barriers have until now inhibited the widespread use of home-monitoring in clinical practice. Two technological developments, low-cost monitors with memory and systems for sending stored readings over the telephone, have the potential of overcoming these barriers.

Unfortunately, accurate readings do not guarantee accurate reporting to the physician. In 2 separate studies, patients were given home monitors, but they were not told that the devices had memory. Patients were urged to carefully record all readings, but in both studies, more than half the subjects omitted or fabricated readings. Devices that have memory or printouts of the readings are therefore recommended.

It is recommended that when readings are taken, the patient should not have recently indulged in any activity such as exercise or eating that is likely to affect the blood pressure, and the patient should be resting quietly in a comfortable chair for 3 to 5 minutes with the upper arm at heart level. Three readings should be taken in succession, separated by at least 1 minute. The first is typically the highest, and the average should be used as the blood pressure reading. It is helpful to get readings in the early morning and the evening.

What Is Normal Home Blood Pressure?

Home blood pressures are consistently lower than clinic pressures in most hypertensive patients. Several recent studies have addressed the question of the level of home pressure that best corresponds to a normal clinic pressure of 140/90 mm Hg. The largest, the Ohasama study, proposed a level of 137/84 mm Hg as an acceptable upper limit for home readings on the grounds that cardiovascular risk increases above this level. An ad hoc committee of the American Society of Hypertension, reviewing several studies, recommended

135/85 mm Hg as the upper limit of normal for home and ambulatory blood pressure. As with office blood pressure, a lower home blood pressure goal is advisable for certain patients, including diabetic patients, pregnant women, and patients with renal failure.

Prognostic Significance

One factor that has held back the wider use of self-monitoring in clinical practice has been the lack of prognostic data. Two prospective studies, 1 from Japan and 1 from France, have found that home blood pressure predicts morbid events better than conventional clinic measurements. There is an increasing body of evidence that home blood pressure may also predict target organ damage better than clinic pressure.

Telemonitoring

Devices are now available that have the capacity to store readings in their memory and then transmit them via the telephone to a central server computer, and then to the health care provider. They have the potential to improve patient compliance and, hence, blood pressure control. Readings taken with a telemonitoring system may correlate more closely than clinic readings with ambulatory blood pressure.

Features of different methods of BP measurement are provided in Table 2 of the original guideline document.

Ambulatory Blood Pressure Measurement

Types of Monitor

Ambulatory blood pressure (ABP) monitoring is a noninvasive, fully automated technique in which blood pressure is recorded over an extended period of time, typically 24 hours. It has been used for many years as a research procedure and has recently been approved by Medicare for reimbursement of a single recording in patients with suspected white-coat hypertension (WCH). The standard equipment includes a cuff, a small monitor attached to a belt, and a tube connecting the monitor to the cuff. Most, but not all, ABP devices use an oscillometric technique. Of the available ABP devices, most have undergone validation testing as recommended by the AAMI or the BHS. An up-to-date list of validated monitors is available.

During a typical ABP monitoring session, blood pressure is measured every 15 to 30 minutes over a 24-hour period including both awake and asleep hours, preferably on a workday. The total number of readings usually varies between 50 and 100. Blood pressure data are stored in the monitor and then downloaded into device-specific computer software. The raw data can then be synthesized into a report that provides mean values by hour and period: daytime (awake), nighttime (asleep), and 24-hour blood pressure, both for systolic and diastolic blood pressure. The most common output used in decision-making are absolute levels of blood pressure, that is, mean daytime, nighttime, and 24-hour values.

The monitors can be attached by a trained technician, who should be skilled in blood pressure measurement techniques (see the previous section on Blood Pressure Measurement in Other Settings). The cuff is attached to the nondominant upper arm, and a series of calibration readings are taken with a mercury sphygmomanometer to ensure that the device is giving accurate readings (within 5 mm Hg of the mercury readings). It is important to instruct the patient to hold the arm still by the side while the device is taking a reading. It may be helpful to ask the patient to keep a diary of activities, particularly when going to bed and getting up in the morning.

Clinical Applications

Although ABP could be used to monitor therapy, the most common application is diagnostic, that is, to ascertain an individual's usual level of blood pressure outside the clinic setting and thereby identify individuals with WCH. Other potential applications of ABP include the identification of individuals with a nondipping blood pressure pattern (e.g., in diabetes), patients with apparently refractory hypertension but relatively little target organ damage, suspected autonomic neuropathy, and patients in whom there is a large discrepancy between clinic and home measurements of blood pressure. The Centers for Medicare and Medicaid Services has approved the use of ABP measurement for the diagnosis of patients with suspected WCH (documented high clinic pressures and normal pressures in other settings, and no evidence of target organ damage).

A recent overview sponsored by Agency for Healthcare Research and Quality summarized available evidence on cross-sectional associations of ABP with subclinical outcomes and on prospective associations of ABP with clinical outcomes. In cross-sectional studies of blood pressure with left ventricular mass (22 studies) and albuminuria (6 studies), ABP levels were directly associated with both measurements. Left ventricular mass was less in individuals with WCH than in those with sustained hypertension but was greater in WCH than in nonhypertensive subjects. Such evidence suggests that WCH is an intermediate phenotype. In each of 10 prospective studies, at least one dimension of ABP predicted clinical outcomes. In studies that compared the prognostic importance of ABP to clinic measurements, ABP was usually superior to clinic measurements. In some instances, including a recent study unavailable at the time of the overview, mean ABP levels provided additional predictive information beyond that of clinic measurements, confirming the seminal study by Perloff et al. In a few prospective studies, WCH predicted a reduced risk of cardiovascular disease events compared with sustained hypertension. However, data were inadequate to compare the risk associated with WCH to the risk associated with normotension. A nondipping or inverse dipping pattern predicted an increased risk of clinical outcomes. Just 2 ABP trials tested the usefulness of ABP to guide blood pressure management. Overall, available studies indicate that ABP monitoring can provide useful prognostic information.

What Is Normal ABP?

The normal range for ABP has been established in 2 ways: first, by comparison of the ABP level that corresponds to a clinic pressure of 140/90 mm Hg and, second, by relating ABP to risk in prospective studies. The suggested values for daytime, nighttime, and 24-hour average levels are shown in the table below.

Suggested Values for the Upper Limit of Normal Ambulatory Pressure			
	Optimal	Normal	Abnormal
Daytime	<130/80	<135/85	>140/90
Nighttime	<115/65	<120/70	>125/75
24-Hour	<125/75	<130/80	>135/85

Prognostic Significance

Several prospective studies have documented that the average level of ABP predicts risk of morbid events better than clinic blood pressure. In addition to mean absolute levels of ABP, certain ABP patterns may predict blood pressure-related complications. The patterns of greatest interest are WCH and nondipping blood pressure. WCH is a pattern in which clinic blood pressure is in the hypertensive range but ABP is normal or low. Individuals with WCH are at lower risk for blood pressure-related complications in comparison to individuals with sustained hypertension. An important but unresolved issue is whether the risk of cardiovascular disease in WCH exceeds that of nonhypertensive subjects. Using both daytime and nocturnal ABP, one can identify individuals, termed nondippers, who do not experience the decline in blood pressure that occurs during sleep hours. Usually, nighttime (asleep) blood pressure drops by 10% or more from daytime (awake) blood pressure. Individuals with a nondipping pattern (<10% blood pressure reduction from night to day) appear to be at increased risk for blood pressure-related complications compared with those with a normal dipping pattern. Other evidence suggests that the nighttime blood pressure may be the best predictor of risk.

Blood Pressure Recording in Special Situations

Elderly Patients

Elderly patients are more likely to have WCH, isolated systolic hypertension, and pseudohypertension (see the section on Pseudohypertension in the original guideline document). Blood pressure should be measured while seated, 2 or more times at each visit, and the readings should be averaged. Blood pressure should also be taken in the standing position routinely because the elderly may have postural hypotension. Hypotension is more common in diabetic patients. It is frequently noticed by patients on arising in the morning, after meals, and when standing up quickly. Self-measurements can be quite helpful when considering changes in dosage of antihypertensive medications. Ambulatory blood pressure monitoring, sometimes coupled with Holter recordings of electrocardiograms (ECGs), can help elucidate some symptoms such as episodic faintness and nocturnal dyspnea.

Pulseless Syndromes

Rarely, patients present with occlusive arterial disease in the major arteries to all 4 limbs (e.g., Takayasu arteritis, giant cell arteritis, or atherosclerosis) so that a reliable blood pressure cannot be obtained from any limb. In this situation, if a carotid artery is normal, it is possible to obtain retinal artery systolic pressure and use the nomogram in reverse to estimate the brachial pressure (oculoplethysmography), but this procedure and the measurement of retinal

artery pressures are not generally available. If a central intra-arterial blood pressure can be obtained, a differential in pressure from a noninvasive method can be established and used as a correction factor.

Arrhythmias

When the cardiac rhythm is very irregular, the cardiac output and blood pressure varies greatly from beat to beat. There is considerable interobserver and intra-observer error. Estimating blood pressure from Korotkoff sounds is a guess at best; there are no generally accepted guidelines. The blood pressure should be measured several times and the average value used. Automated devices frequently are inaccurate for single observations in the presence of atrial fibrillation, for example, and should be validated in each subject before use. However prolonged (2 to 24 hours) ambulatory observations do provide data similar to that in subjects with normal cardiac rhythm. Sometimes, an intra-arterial blood pressure is necessary to get a baseline for comparison. If severe regular bradycardia is present (e.g., 40 to 50 bpm), deflation should be slower than usual to prevent underestimation of systolic and overestimation of diastolic blood pressure.

Obese Patients

A longer and wider cuff is needed for adequate compression of the brachial artery in the obese patient with a very large upper arm (see the previous section on Cuff Size). A large cuff may also be required for a big, muscular arm with a prominent biceps over which a regular, nontapered cuff might not fit smoothly. In both situations, it is particularly important to place the center of the bladder over the brachial artery pulse. If the upper arm is relatively short despite the large circumference, it may be difficult to fit a standard large adult cuff over the arm. The BHS's recommendation to use a very long cuff (12X40 cm; BHS web site August 13, 2003, www.bhsoc.org/bp_monitors/BLOOD_PRESSURE_1784b.pdf) could obviate this problem. In the rare patient with an arm circumference >50 cm, when even a thigh cuff cannot be fitted over the arm, it is recommended that the health care practitioner wrap an appropriately sized cuff around the patient's forearm, support it at heart level, and feel for the appearance of the radial pulse at the wrist. Other potential methods for measuring radial artery pressure include listening for Korotkoff sounds over the radial artery, detecting systolic pressure with a Doppler probe, or using an oscillometric device to determine systolic blood pressure; diastolic blood pressure is largely overestimated by both methods. The accuracy of these methods has not been validated, but they provide at least a general estimate of the systolic blood pressure. The error of overestimating the pressure when measuring with a cuff that is too small for an obese arm can be considerable and can lead to misclassification of an individual as hypertensive and to unnecessary concern and therapy.

Children

Blood pressure is most conveniently measured in children by auscultation with a standard mercury sphygmomanometer. As with adults, the stethoscope is placed over the brachial artery pulse, proximal and medial to the antecubital fossa, and below the bottom edge of the cuff. The right arm is generally the preferred arm

for blood pressure measurement for consistency and comparison with the reference tables.

Correct blood pressure measurement in children requires the use of a cuff that is appropriate for the size of the child's upper arm. A technique that can be used to select a blood pressure cuff size of appropriate size is to select a cuff that has a bladder width that is at least 40% of the arm circumference midway between the olecranon and the acromion. This will usually be a cuff bladder that will cover 80% to 100% of the circumference of the arm. The equipment necessary to measure blood pressure in children 3 years of age through adolescence includes pediatric cuffs of different sizes. For newborn-premature infants, a cuff size of 4X8 cm is recommended; for infants, 6X12 cm; and for older children, 9X18 cm. A standard adult cuff, a large adult cuff, and a thigh cuff for leg blood pressure measurement and for use in children with very large arms should also be available.

Blood pressure measurements in children should be conducted in a quiet and comfortable environment after 3 to 5 minutes of rest. With the exception of acute illness, the blood pressure should be measured with the child in the seated position with the antecubital fossa supported at heart level. It is preferable that the child has feet on the floor while the blood pressure is measured, rather than feet dangling from an examination table. Overinflation of the cuff should be avoided because of discomfort, particularly in younger children. It is useful to initially inflate the cuff while palpating the pulse to estimate the approximate range for the systolic pressure and then inflate the cuff to 30 mm Hg above this estimate when the blood pressure is auscultated. The blood pressure should be measured and recorded at least twice on each measurement occasion, and the average of these 2 measurements is the measurement for systolic and diastolic blood pressure.

Systolic blood pressure is determined by the onset of the auscultated pulsation or first Korotkoff sound. The phase of the Korotkoff sounds that defines diastolic blood pressure has been somewhat controversial. The disappearance of Korotkoff sounds or fifth Korotkoff sound (K5, the last sound heard) is the definition of diastolic pressure in adults. In children, particularly preadolescents, a difference of several millimeters of mercury is frequently present between the fourth and fifth Korotkoff sounds. In some children, the Korotkoff sounds can be heard to 0 mm Hg, which has limited physiological meaning.

Elevated blood pressure measurements in a child or adolescent must be confirmed on repeated visits before characterizing a child as having hypertension. Within individual children, blood pressure at high levels tends to fall on subsequent measurement as a result of an accommodation effect (reduction of anxiety as the circumstances become more familiar) and regression to the mean, a nonbiological phenomenon that derives, in part, from mathematical considerations. Therefore, a more precise characterization of an individual's blood pressure level is an average of multiple blood pressure measurements taken for weeks or months. A notable exception to this general guideline for asymptomatic generally well children would be situations in which the child is symptomatic or has profoundly elevated blood pressure. Children who show elevated blood pressure on repeated measurement should also have the blood pressure measured in the leg as a screen for coarctation of the aorta. To measure the blood pressure in the leg, a thigh cuff or an oversized cuff should be placed on the thigh and the blood pressure measured

by auscultation over the popliteal fossa. If the systolic blood pressure measured in the thigh is >10 mm Hg lower than the systolic blood pressure measured in the arm, additional studies for coarctation should be performed.

There continues to be an increase in the use of automated devices to measure blood pressure in children. These devices are easier to use and are becoming alternative instruments for blood pressure measurement when use of mercury sphygmomanometers is not permitted for ecological reasons. The most commonly used devices use oscillometric methods (see the previous section on The Oscillometric Technique). Situations in which the use of the automated devices is acceptable include blood pressure measurement in newborn and young infants in whom auscultation is difficult, as well as in an intensive care setting, where frequent blood pressure measurement is necessary. The reliability of these instruments in an ambulatory clinical setting is less clear, however.

The interpretation of the blood pressure measurement in children requires consideration of the child's age, sex, and height. Hypertension in children and adolescents is defined as systolic and/or diastolic blood pressure that is consistently equal to or greater than the 95th percentile of the blood pressure distribution. Tables are available that provide the systolic and diastolic blood pressure level at the 95th percentile according to age, sex, and height. These tables should be consulted to determine if the blood pressure measurements are normal or elevated. Children also demonstrate white coat effects, but the role of ambulatory blood pressure monitoring is less clear in children. Validated devices should be used, preferably in a center with experience using ABPM. Large population-based normative data in children using ABPM are limited.

Pregnant Women

Hypertension is the most common medical disorder of pregnancy and occurs in 10 to 12% of all pregnancies. The detection of elevated blood pressure during pregnancy is one of the major aspects of optimal antenatal care; thus, accurate measurement of blood pressure is essential. Mercury sphygmomanometry continues to be the recommended method for blood pressure measurement during pregnancy. Blood pressure should be obtained in the seated position. Measurement of blood pressure in the left lateral recumbency, on the left arm, does not differ substantially from blood pressure that is recorded in the sitting position. Therefore, the left lateral recumbency position is a reasonable alternative, particularly during labor. If the patient's upper arm circumference is 33 cm or greater, a large blood pressure cuff should be used. In the past, there had been some question as to whether the fourth (K4) or fifth (K5) Korotkoff sound should be used to define the diastolic blood pressure. The International Society for the Study of Hypertension in Pregnancy currently recommends using K5 for the measurement of diastolic blood pressure in pregnancy. When sounds are audible with the cuff deflated, K4 should be used.

It is recognized that alternatives to mercury devices may be necessary in the future, and a small number of automated blood pressure recorders have been validated for use in pregnancy. Self-monitoring may be useful in evaluating blood pressure changes during pregnancy.

Summary and Recommendations

Accurate measurement of blood pressure is essential to classify individuals, to ascertain blood pressure-related risk, and to guide management. The objective of this report is to provide clinicians with a standardized set of recommendations that, if followed, should lead to accurate estimation of blood pressure. The guideline developers recognize that many committees and organizations have published recommendations and that, in practice, blood pressure measurement remains suboptimal. In view of the consequences of inaccurate measurement, including both the risks of overtreatment and undertreatment, it is the opinion of the committee that regulatory agencies should establish standards to ensure the use of validated devices, routine calibration of equipment, and the training and retraining of manual observers. Because the use of automated devices does not eliminate all major sources of human error, the training of observers should be required even when automated devices are used.

CLINICAL ALGORITHM(S)

None provided

EVIDENCE SUPPORTING THE RECOMMENDATIONS

TYPE OF EVIDENCE SUPPORTING THE RECOMMENDATIONS

The type of supporting evidence is not specifically stated for each recommendation.

BENEFITS/HARMS OF IMPLEMENTING THE GUIDELINE RECOMMENDATIONS

POTENTIAL BENEFITS

Accurate estimation of blood pressure may help to classify individuals, ascertain blood pressure-related risk, and guide management

POTENTIAL HARMS

- Environmental concerns about mercury contamination exist with the mercury sphygmomanometer.
- The consequences of inaccurate measurement include both the risks of overtreatment and undertreatment of hypertension.

IMPLEMENTATION OF THE GUIDELINE

DESCRIPTION OF IMPLEMENTATION STRATEGY

An implementation strategy was not provided.

INSTITUTE OF MEDICINE (IOM) NATIONAL HEALTHCARE QUALITY REPORT CATEGORIES

IOM CARE NEED

Living with Illness
Staying Healthy

IOM DOMAIN

Effectiveness

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FINANCIAL DISCLOSURES/CONFLICTS OF INTEREST

The American Heart Association makes every effort to avoid any actual or potential conflicts of interest that may arise as a result of an outside relationship or a personal, professional, or business interest of a member of the writing panel. Specifically, all members of the writing group are required to complete and submit a Disclosure Questionnaire showing all such relationships that might be perceived as real or potential conflicts of interest.

Disclosure

Writing Group Member Name	Research Grant	Speakers Bureau/Honoraria	Stock Ownership	Consultant/Advisory Board	Other
Dr Thomas G. Pickering	None	None	None	None	Patent holder of Accusphyg blood pressure monitor
Dr John E. Hall	None	None	None	None	None
Dr Lawrence J. Appel	None	None	None	None	None
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This table represents the relationships of writing group members who may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit.

GUIDELINE STATUS

This is the current release of the guideline.

GUIDELINE AVAILABILITY

Electronic copies: Available from the American Heart Association Web site:

- HTML Format
- Portable Document Format (PDF)

Print copies: Available from the American Heart Association, Public Information, 7272 Greenville Ave, Dallas, TX 75231-4596; Phone: 800-242-8721

AVAILABILITY OF COMPANION DOCUMENTS

None available

PATIENT RESOURCES

None available

NGC STATUS

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